CREDA

New Home Construction: Eric Allen

CREDA is a program which has been jointly funded by Energy, Mines and Resources, Canada and the Yukon Government, Department of Economic Development and Tourism. For more information or copies of reports contact the Energy and Mines Branch, Yukon Government, Box 2703, Whitehorse, Y1A 2C6.

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1. FOREWORD

The availability of secure and affordable energy supplies is a subject of national concern. Our primary energy sources are becoming more costly and less accessible. However, Canada has both the resources and technical expertise needed to develop renewable and alternative sources of energy.

The governments of Yukon and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement as one means of pursuing this end. Cost shared by the territorial and federal governments, CREDA has a budget of $3.3 million and is dedicated to the development and demonstration of conservation and renewable energy technologies.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

The project described in this report is an attempt to develop awareness of new ideas and construction methods in making houses energy efficient. Although construction methods have improved and insulation levels are higher than they were 10 - 20 years ago, the majority of houses continue to have minimum levels of insulation and a multitude of small air leaks. The newest theory is to "wrap and strap" and to compromise between "mass and glass."

2. EXECUTIVE SUMMARY

The following report describes some special energy efficient measures incorporated in the construction of a modestly-priced two and a half storey frame house with a floor area of 108 m². It was felt that the extra expenses incurred during construction would pay for themselves within five to six years. The house was built facing south, on a south-sloping lot with a thick stand of Jack Pine on the north side.

The major energy efficient measures are: (1) continuous air-vapour barrier and high insulation level to make the house as air-tight as possible; (2) the use of passive solar heat which is expected to supply 37 per cent of the annual heating requirements; (3) a crawlspace plenum which draws hot air from the top of the house and recirculates it under the first floor; and (4) horizontal strapping for extra insulation and on which all wall partitions, electrical and plumbing work was done in order not to break the continuous air-vapour barrier.

Other measures include an air-to-air heat exchanger, and provision for thermal mass in the plenum for heat storage. All seams in the air-vapour barrier were sealed on studs with caulking. Special attention was paid to weather stripping around the doors and windows.

3. Résumé pour l'exécutif

Le rapport suivant décrit quelques mesures à haut rendement énergétique spéciales incorporées dans la construction d'une maison en bois, à prix modéré, ayant une surface de plancher de 108 m^2 répartie sur deux étages et demi. On a estimé que le recouvrement des dépenses additionnelles encourrues durant la construction s'effectuerait en moins de 5 ou 6 ans. La maison a été construite face au sud, sur un terrain allant en pente vers le sud et qui possède un épais bouquet de "Jack Pine" du côté nord.

Les principales mesures à haut rendement énergétique sont:
(1) un coupe-vapeur ininterrompu et un haut niveau d'isolation pour rendre la maison aussi étanche à l'air que possible;
(2) l'utilisation de la chaleur passive du soleil dont on s'attend à ce qu'elle fournisse 37% des besoins annuels en chauffage;
(3) une chambre de ventilation (envion 60 cm de haut, située sous le 1^e plancher) où l'on aspire, grâce à un éventail et à un système de conduits secondaires, l'air chaud accumulé dans le haut de la maison pour le faire circuler sous le 1^e plancher; et
(4) pour contenir les matériaux isolants supplémentaires, des lattes horizontales auxquelles on a fixé les éléments de plomberie, d'électricité et les cloisons de façon à ne pas interrompre la continuité de la barrière formée par le coupe-vapeur.

Les autres mesures incluent un échangeur de chaleur air-air, et on a prévu l'installation dans la chambre de ventilation d'un système de rétention thermique servant à emmagasiner la chaleur passive. Tous les joints du coupe-vapeur ont été scellés en place sur les colombages de cloison avec du goudron à calfeutrer. On a porté une attention toute particulière aux bourrelets posés autour des portes et des fenêtres ouvrantes.

Les rapports indiquent qu'entre septembre 1981 et juin 1982 on n'a utilisé que quatre cordes de bois. Des tests d'étanchéité ont montré un taux d'infiltration d'air de 2,5 ac/H à 50 Pa. Ceci représente environ la moitié du taux d'une maison de format moyen, assez récente et bien isolée.

Toutes les mesures employées, qui sont faciles à incorporer à la construction et qui ne requièrent pas de gadgets dispendieux, semblent être efficaces au point de vue de la réduction des besoins annuels en chauffage.

4. INTRODUCTION

We are constantly aware of the rising cost of energy, how much of our dollar goes toward heating, and the possibility of fuel shortages. All this has resulted in an continual search for better ways to build energy efficient homes. Conservation is now being regarded as an energy supply option.

To demonstrate new and innovative techniques in building energy efficient homes Messrs. Allen and Walker[1] in conjunction with the Canada/Yukon Conservation and Renewable Energy Demonstration applied these techniques in the construction of a modestly priced, two and a half storey frame house.

In designing energy efficient homes the basic idea is to reduce heat losses to such an extent that most of the space heating requirements can be met by internal or passive solar gains. The internal gains, present in every home, are from electrical appliances, lighting and people. These internal gains, with passive solar heat, can supply nearly half of the heat required by a relatively well-insulated conventional home. In an energy efficient home internal gains and passive solar heat can supply

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1. As Mr. Walker left the project, the house will be referred to as the Allen house.

a much greater portion of the heating requirements. Figure 1 compares the approximate heat loss and heat gain in conventional and energy efficient homes.

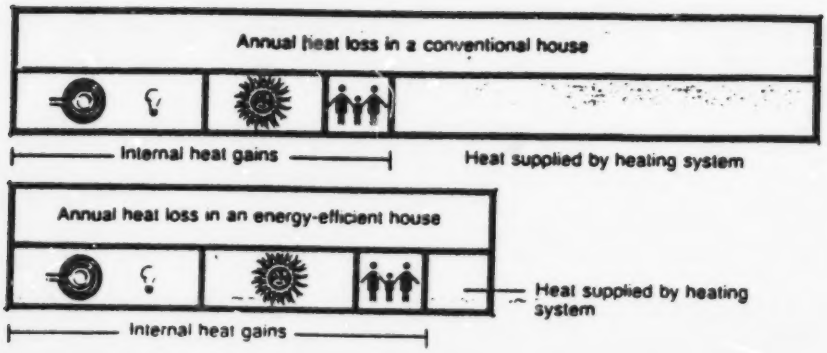
Annual heat loss in a conventional house
Internal heat gains
Heat supplied by heating system
Annual heat loss in an energy-efficient house
Heat supplied by heating system
Internal heat gains

Figure 1. Comparison of approximate heat loss and heat gain in conventional versus EE housing

Most of the attention is focused on preventing heat loss. While internal gains remain the same, solar gains are augmented as much as possible.[2]

There are four main principles which are applied to the design and construction of energy efficient housing. These are high levels of insulation, airtight construction, controlled air management, and passive solar design. Each of these principles plays a key role in the energy efficient home and has been used in the Allen house. They are easy to incorporate into construction, and, although they do increase the cost by approximately 5 to 10%, there is no expensive gadgetry or highly technical equipment that is baffling to the average homeowner or builder.

2. CMHC, Energy-Efficient Housing Construction, 1982

Records kept between September 1981 and June 1982 showed that only four cords of wood were used. Air-tightness tests showed an infiltration rate of 2.5 air changes per hour at 50 Pa. This is about half the rate for a fairly recent, well-insulated, average size house.

5. GENERAL DESCRIPTION OF THE HOUSE

The house is a two and a half storey frame structure with 108 square metres (m^2) of floor space and a surface envelope of 170 m^2. The closer the shape of a house is to a cube, the more energy efficient it is. It faces south on a south sloping lot and has a greenhouse against the lower south wall. There is a thick stand of Jack Pine on the north side to act as a wind break.

The main floor consists of a den-guest room, kitchen, living room-dining room area, and bathroom. The open area concept results in more even heating as air is able to circulate more freely. The upper floor consists of three bedrooms and has an open-beam ceiling with rafters supported by a ridge beam.

The crawlspace under the first level is very well insulated and is used as a hot-air circulator as part of the heating system.

The primary heating source is wood with passive solar heating as a major supplement. Electric baseboard heating is available as a back-up if the house is left unattended for long periods.

The walls are standard 2" x 6" stud walls with RSI 3.5 fibreglass batt insulation, and 6 mil polyethylene plastic (poly) air-vapour barrier. Strapping was applied horizontally over the air-vapour barrier using 2" x 3"'s. All wiring, plumbing and interior partitions were done on the strapping in order not to break the continuous air-vapour barrier.

In order to make the house as air-tight as possible the air-vapour barrier is kept continuous throughout the height of the building. Figure 2 illustrates how this is achieved.

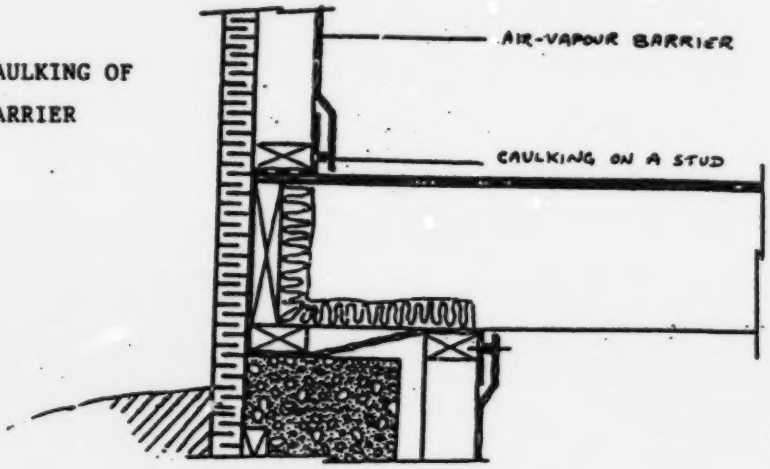

FIGURE 2. CAULKING OF AIR-VAPOUR BARRIER

The south wall has maximum window area to benefit from passive solar energy, while the north wall has minimum window area. An air-to-air heat exchanger was installed to bring fresh air into the house and exhaust stale air without losing precious energy.

Each facet in making the house energy efficient is described in greater detail. The house was built in 1981 and the energy efficient techniques and materials were fairly new and innovative at the time. Techniques and materials have improved in the last four years as the concept of energy efficient houses has become more popular. A great deal of care and attention to details went into the building of the Allen house, and the importance of this cannot be over-emphasized.

6. WALL CONSTRUCTION

The exterior walls are constructed of 2" x 6" kiln dried (KD) spruce studs at 2' centres, and insulated with RSI 3.5 fibreglass batt insulation. Six mil poly air-vapour barrier was installed on the warm side of the fibreglass.

Before the concepts of air infiltration and exfiltration and air-vapour barriers became popular, the vapour barrier was often broken in order to install electrical outlets, pipes, and vents. This meant there was an exchange of air and moisture between the house and its surroundings. In the Allen house this problem was overcome by installing 2" x 3" KD spruce strapping horizontally at 2' centres over the air-vapour barrier. All the electrical wiring, switches, outlets, plumbing, and interior wall partitions are on the warm side of the air-vapour barrier without breaking it. Any seams in the air-vapour barrier were caulked on a stud with geo-seal caulking. RSI 1.8 fibreglass insulation was installed between the strapping to bring the total insulation to a RSI 5.3 level. The interior wall was finished with wood panelling or ½" drywall, and the exterior wall was finished with 1" x 2" cedar battens and ½" cedar faced plywood.

Insulation should be continuous in order to be most effective. The studs in the wall reduce the insulating value of that wall by creating a thermal bridge through which the heat can pass. Insulation value of fibreglass in a 2" x 6" stud wall is RSI 3.5, while the studs are rated at only RSI 1.0. Cross strapping, as has been done in the Allen home, is

one method of reducing the amount of thermal bridging.[3] The thermal bridging has been reduced to an area of 1½" x 1½" where the 2" x 6" studs intersect the 2" x 3" strapping.

New houses built to air-tight, super-insulated standards have RSI 4.4 to RSI 7.0 in the walls. The Allen home has RSI 5.3. A HOTCAN (National Research Council of Canada) survey estimated the walls would account for 16.3% of the seasonal heat loss. This is equivalent to 3.85 GJ out of a total annual heating requirement of 23.61 GJ.

By caulking seams in the air-vapour barrier and not breaking it to install electrical outlets, plumbing etc., the amount of air infiltration can be reduced by about 20%.[4]

3. B. Marshall and R. Argue, The Super-Insulated Retrofit Book, 1981.
4. Ibid.

7. CRAWLSPACE

7.1 Description

The foundation wall consists of a 0.6 m crawlspace designed to be used as a hot air circulator with the possibility of containing some form of thermal mass for heat storage. This new concept, called the Plen-wood system, is an integral part of the heating system and is described in more detail in section 7.2.

The walls are built with pressure treated (PT) 2" x 6" studs at 2' centres and insulated with RSI 3.5 fibreglass insulation. Six mil poly air-vapour barrier, continuous with the air-vapour barrier on the walls above, was placed over the insulation. Caulking of seams was done on solid wood. Horizontal 2" x 3" strapping with RSI 1.8 fibreglass insulation was installed, like it was in the upper walls. The exterior part of the wall was finished with ½" PT plywood and 1½" rigid styrofoam of RSI 1.2. Total insulation value of the walls is RSI 6.5.

The air-vapour barrier is continued down over the footings and forms a continuous sheet under the flooring. There is 2" rigid styrofoam, RSI 1.7, under the concrete floor.

The crawlspace, according to the HOTCAN survey, is expected to account for 15.8% of the seasonal heat loss. This is equivalent to 3.73 GJ of the estimated annual space heating requirement of 23.61 GJ.

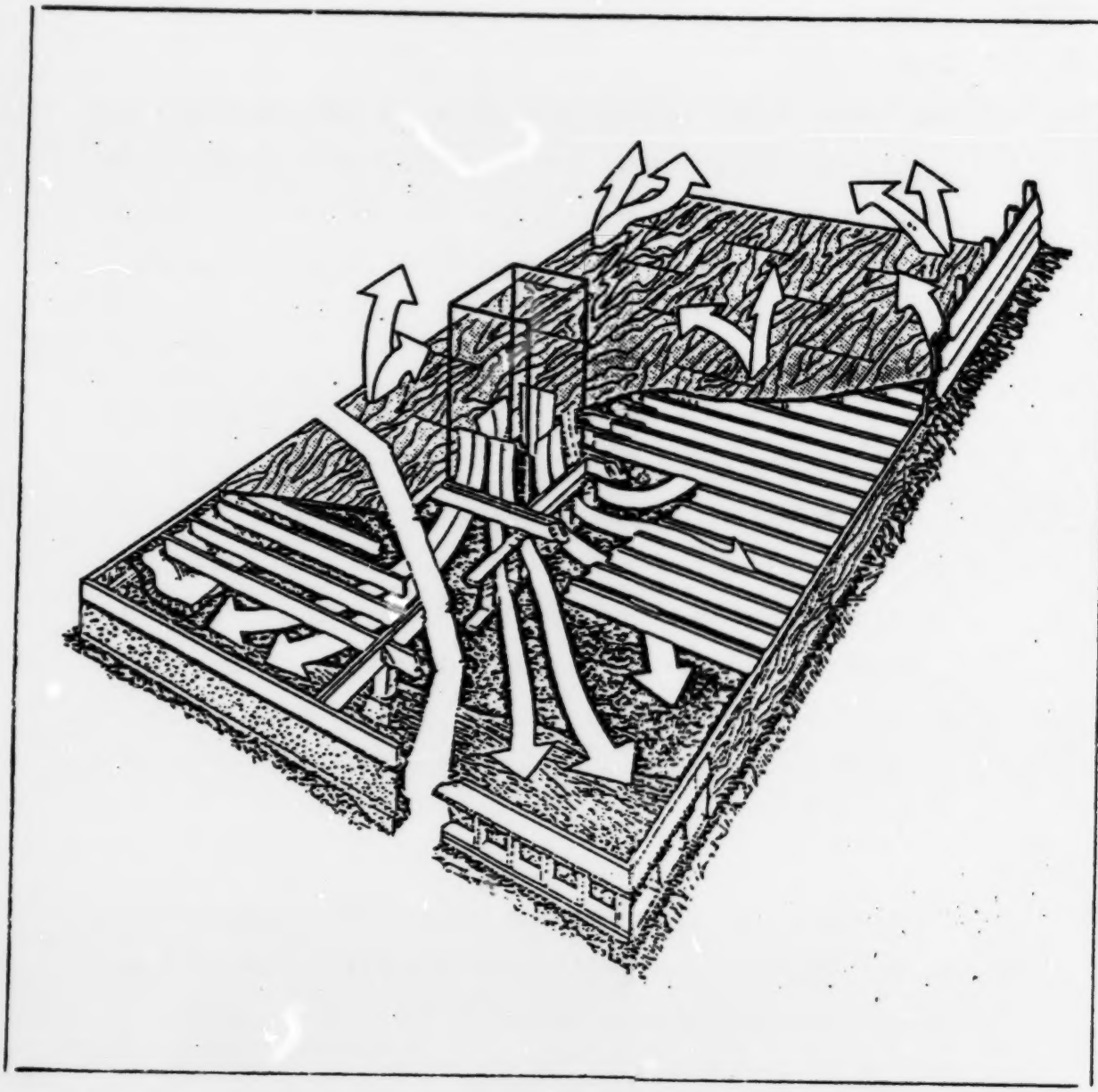

FIGURE 3 THE PLENWOOD SYSTEM FOR CIRCULATING WARM AIR

The heat loss is broken down in the following way:

	% of seasonal heat loss	heat loss in GJ
Crawlspace wall-grade to 0.6 m below grade	2.10	.50
Crawlspace wall-0.6 m below grade to floor	3.18	.75
Floor area 1 m perimeter	7.30	1.72
Floor - centre area	3.20	.76
	15.78	3.73

7.2 Plenwood System

The plenwood system uses a single under-the-floor plenum chamber of at least 0.5 m height to move heated air through the house, instead of using conventional sheet metal ducts. Warm air from the highest part of the house is drawn down into this superinsulated plenum, via a duct in a central interior wall. A fan or a standard furnace will draw the air down. The warm air is then recirculated up into the rooms above via floor registers. The rooms above are actually heated in two ways: the air is circulated by the fan and rises through the floor registers, and heat radiates from the warm floor into the room. There are no restrictions on the type of foundation used, provided it is sealed and insulated to conform to the system's requirements. Construction costs are lower as no expensive ductwork is necessary. Figure 3 illustrates the system.

8. WINDOWS

The size and location of the windows were incorporated in the overall energy-efficient design of the house to maximize solar gain on the south side and to minimize heat losses on the other sides. All the windows are wood framed and double glazed. Their insulation value is RSI 0.36, and they have a shading coefficient of 0.83. Special attention was paid to caulking and insulating around the windows when they were installed.

The total window area is 15.8 m² or 9% of the total surface envelope. Details on size and heat loss data is given below in Table 1.

TABLE 1

DATA ON WINDOW SIZE AND HEAT LOSS FROM HOTCAN SURVEY

Location	Area m²	% of Total Window Area	% of Seasonal Heat Loss	Heat Loss GJ
North	0.7	4.4	1.92	0.45
South	9.3	58.9	25.46	6.01
East	3.6	22.8	9.85	2.32
West	2.2	13.9	6.02	1.42
Total	15.8	100.0	43.25	10.20

Generally, in an energy-efficient house, if south-facing windows amount to more than the equivalent of six or seven per cent of the heated floor area, it becomes necessary to provide shading and/or additional mass to store and use the extra heat.[5]

5. Ibid

The south-facing windows in the Allen house are 8.6% of the floor area, but it is questionable if heat storage is necessary as the window area is only fractionally larger than the six or seven per cent guideline.

This six or seven per cent guideline is for houses in the south and may not be applicable for houses in the far north. The summers are generally cooler and over-heating problems are uncommon where passive solar heating is used.

9. DOORS

The doors are made of wood with insulation on the inside, and they have a an insulating value of RSI 2.0. There are two doors on the west, totalling 6.0 m^2. It is estimated on the HOTCAN survey that they will account for 3% of the total seasonal heat loss, or the equivalent of 0.70 GJ. Special attention was paid to caulking and insulation when they were installed.

10. CEILING AND ROOF

The ceiling is an open beam type. Site built rafters of 2" x 8" and 2" x 4"'s are held with gussets to form the cathedral peaked ceiling on the top floor. The ceiling has a area of 50.4 m^2 and a RSI value of 10.0. Heat loss through the ceiling is expected to be only 5% of the seasonal heat loss, the equivalent of 1.17 GJ. The pitch of the roof is 10 : 12 in order to give headroom in the upper floor, but it is not too steep for access for chimney cleaning. Again, the air-vapour barrier is continuous from the walls and any seams were caulked on solid wood.

11. DOMESTIC HOT WATER

The 180 litre domestic hot water tank is located in the kitchen and is within three metres of end use to reduce loss of heat in the pipes. The kitchen and the bathroom are back-to-back. The tank is electrically heated and has a special insulating blanket around it.

12. HEATING AND VENTILATION

12.1 Description

The main sources of heating in the Allen home are wood and passive solar energy. Electric baseboard heaters were installed as a backup for periods when the house is left unoccupied.

A Franklin-type air-tight wood stove is located in a central position on the main floor on a brick pad. The open area design of the main floor helps to distribute the heat more evenly. A duct in a central interior wall, with an intake grill located in ceiling on the top level, is used to recirculate the warm air from the top of the building. This warm air is drawn down into the heating plenum by a fan. It keeps the floor warm and circulates up through the floor vents. This way there is no need for expensive ductwork found in conventional houses.

Passive solar heating is expected to provide 37% of the annual heating requirements, and be the only source of heating for five months of the year, May to September inclusive. It could supply nearly two-thirds of the heating needs for April and October.

Because fresh air transfer from the outside to inside is greatly reduced in an air-tight house such as the Allen house, it becomes necessary to install an air-to-air heat exchanger. A vanEE air

exchanger at 80% efficiency was installed. Besides exhausting stale air and providing fresh air, the air-to-air heat exchanger also helps to control the build-up of moisture that is common in air-tight houses. The air-vapour barrier effectively locks in the approximately 63.0 litres of moisture generated weekly in a typical household by the combined effects of respiration, cooling, laundering and bathing.[6]

12.2 Heating Requirements

The HOTCAN survey predicted the annual space heating requirements would be 23.61 GJ, or 6,550 kWh. Table 2 gives the heat loss summary. This annual heating requirements could be met by: (1) 865 litres of oil (at 70% efficiency) at $.45 litre, which amounts to $389; (2) 6,559 kWh at $.063, which amounts to $413; or (3) 2.6 cords of wood at $60/cord, which amounts to $152.

TABLE 2
HEAT LOSS SUMMARY
ESTIMATED ANNUAL SPACE HEATING REQUIREMENT - 23.61 GJ or 6,559 kWh

	Area M^2	RSI Value	% Seasonal Heat Loss	Heat Loss GJ
Ceiling	50.40	10.00	4.97	1.17
Main Walls	86.10	5.20	16.32	3.85
Doors	6.00	2.00	2.96	.70
Crawlspace Walls	39.20	5.20	5.28	1.25
Crawlspace Floor	37.80	1.70	10.51	2.48
Windows	15.80	0.36	43.24	10.21
Air Change .25/hr	220.00		16.22	3.95
			100.00	23.61

6. EMR Canada, Keeping The Heat In, 1983.

The national average annual space heating requirement for houses north of 60^{0} latitude is 4,100 litres of oil. The predicted annual heating requirements of the Allen house, at 865 litres, is 21% of the national average. In 1985 the cost for 4,100 litres at $.45 per litre is $1,865.50. The HOTCAN prediction of heating the Allen house would be $389.25 in 1985. This amounts to a savings of $1,471.90 or 79%. Although oil is not used, the potential savings are considerable.

Wood is, in fact, the main source of space heating. From September 1981 to June 1982 four cords of wood were used. A cord of typical fire-killed wood in the Yukon produces approximately 16.6 GJ of energy. With 50% efficiency from a wood stove, the actual heat derived from a cord would be about 8.3 GJ. A total of 33.2 GJ of energy was used to heat the house, which is 40% more than predicted.

There are a number of factors which can account for the extra consumption. There was less solar heating than predicted. The measurement of four cords may not be truly accurate as there is often some discrepancy in the amount of wood in a cord due to the size of the logs, and the way in which they are stacked. The HOTCAN prediction was based on temperature of 17^{0} C in the house, when, in fact, wood heat is inconsistent, often resulting in temperatures considerably higher than 17^{0}C. Although the HOTCAN survey suggests that solar heat could supply the total heating requirements from May

to September inclusive, it is doubtful that this could be done, particularly in September. There are often cool, cloudy days throughout the whole summer when wood heat would be needed to supplement solar heat.

12.3 Air Changes

The HOTCAN survey estimated the natural infiltration rate would result in 0.25 air changes per hour (AC/HR). In conventional houses the infiltration rate ranges from 0.2 to 1.5 AC/hr.[7] Air infiltration or exfiltration can account for 30 to 40 per cent of the heat loss in a typical house.[8] The HOTCAN survey estimated the seasonal heat loss from natural air change would be 16.72%. This compares favourably with conventional houses.

Three airtightness tests done by Northern Retrofit, Whitehorse, gave the following results:

Date	Time	AC/hr @ 10 PA	AC/hr @ 50 PA
May 28/82	11:15 am	--	2.44
Sept 10/82	11:00 am	.67	2.16
Sept 10/82	3:30 pm	1.18	3.06

This is about half the rate for the average-size conventional house.

7. CMHC, Air-Vaour Barrier, 1983

8. R. Argue, The Well - Tempered House, 1980

13. BUDGET REVIEW

Budget to Actual	Budget	Actual
Insulation	$1,141.00	$959.24
Air-to-air Heat Exchanger	800.00	645.00
Lumber	450.00	375.34
Shutter Material	300.00	--
Caulking	150.00	103.90
6 mil Polyethylene	90.00	59.90
Labour	1,100.00	335.00
Freight		36.22
Information Transfer		13.89
Total	$4,210.00	$2,528.49

The actual cost of making the house energy efficient was $1,681.51 under the estimated price. Part of the reason was that the materials cost about 30% less than estimated. The 67 hours of labour for the extra work in making the house energy efficient was done by the proponents themselves for $5.00 per hour. The same amount of time charged at contractors' rate of $30.00 would come to $2,010.00.

14. ECONOMIC BENEFITS

The cost of making the house energy efficient was $2,500. The price of the house on completion was projected to be $65,000. The cost for the energy efficiency measures is four per cent of the total.

If the house can be heated with four cords of wood @$60/cord, the annual heating bill would be $240. For a conventional house of the same size, using wood, the heating bill would be from $750 to $1,000. It is impossible to get an exact idea of the heating costs of a conventional house to calculate the savings, but it is reasonable to assume an annual saving of $500 to $750 could be realized in the Allen house. The payback period would be from three to five years.

As mentioned earlier, the possible savings if oil were used for heating the Allen home are approximately $1,500. The payback period would then be less than two years.

Considering the small percentage of the total building cost, and the short time for the return on the investment, it appears that energy efficient measures are a very worthwhile investment of time and money.

15. POTENTIAL REPLICATION

Any house being built has the potential to be made energy efficient in the same manner as the Allen house. The cost is a very small percentage of the total cost of the house and the payback period is a relatively short time. The principles are easy to understand and can be applied to any new building during construction without any changes in the plans or design of the house. New techniques and materials are becoming available all the time as the building of energy efficient houses becomes more popular.

These energy efficient measures need not be limited to houses. Multi-family dwellings, hotels, motels, offices, commercial and industrial buildings can also be made energy-efficient.

16. CONCLUSIONS

The Allen house is a good example of how an investment of a small percentage of the total cost, and about 67 hours of work, can result in an energy efficient house. The resulting savings on energy bills can be quite significant and can mean a return on the investment within five years.

There are other advantages as well. Making houses energy efficient will help save valuable non-renewable energy resources. A well-insulated energy efficient house is a comfortable home, free from drafts, warmer in winter and cooler in summer.

Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

Yukon
Department of Economic Development and Tourism

NEW HOME CONSTRUCTION: ERIC ALLEN

Final Project Summary

Canada/Yukon Conservation and Renewable Energy Demonstration Program

Project No.
3766-4-9

Date:
February, 1985

Sectors:
Energy Efficient House

Project Locations:
Whitehorse

Technology:
Conservation

Jurisdiction:
Yukon

Project Manager:
Eric Allen

Status:
Complete

Simple Payback
5 years

Purpose:

The project was to demonstrate the feasibility of applying some innovative construction techniques to make a new house energy efficient.

Description:

A 108 m², two and half storey frame house was superinsulated and made air-tight. A method of recirculating hot air was incorporated by drawing it down from the top of the house with a fan via a duct in the wall to a well sealed and insulated crawlspace plenum. It then rises through vents in the main floor. Passive solar heat is also used, with thermal mass in the crawlspace plenum.

Contributors:

Applicant	$ 858.39
Canada/Yukon	1,730.89
	$2,589.28

Further Information:

Mr. Eric Allen, 16 Tamarack, Whitehorse, Yukon (403) 633-2251
Mr. David Arseneault, Information Officer, Energy and Mines Branch, Economic Development and Tourism, Government of Yukon, P.O. Box 2703, Whitehorse, Yukon (403)667-5384.

Economic Analysis:

For the winter of September 1981 to May 1982 only four cords of wood were used, which is at least half the requirement of a conventional house the same size.

Materials	$1,548.49
Air-to-air Exchanger	645.00
Labour	335.00
	$2,528.49

The cost was 4% of the total projected cost of the house. The payback period is expected to be within five years.

Technical Details:

There were four basic energy saving principles applied in the construction of the house. They are super insulation, air-tight vapour barrier, passive solar heating, and controlled air management with an air-to-air heat exchanger. Horizontal strapping with 2" x 3"'s was placed over the air-vapour barrier, and all electrical and plumbing work was done inside the air-vapour barrier. All seams in the air-vapour barrier were caulked on solid wood.